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ABSTRACT

This paper reports on research designed to examine relationships among analogical reasoning, Piagetian level, and physics achievement. A sample of 37 college students enrolled in a physics course participated in a three-day study and were given tasks designed to measure analogical reasoning ability and Piagetian level. Course achievement was indicated by individual scores on the mid-term examination, final examination, and total course score. The study suggests that a change to paragraph form no longer necessitates the use of proportional reasoning, nor is the paragraph form related to Piagetian level as in the A:B::C:x type of analogy. Data indicate that paragraph analogies do not aid comprehension of a concept, and that analogies found in science texts do not enhance achievement. (Author/GA)

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Analogy and Physics Achievement

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Introduction

Science educators, perceiving the importance of analogy in science, have frequently utilized analogies as a pedagogical tool. Beeler (1954) surveyed elementary science texts published from 1800-1952 and found an average of fourty-one analogies per book. That this extensive use of analogies has continued to the present is suggested by the fact that one recently published secondary chemistry text (Choppin, Summerlin, and Jaffe, 1978) advertises a frequent use of analogies as a major selling point. Weller (1970) suggests that science educators' justification of this faith in analogies is intuitively based in the following rationale.

> If a scientist finds an analogy helpful in developing a theory, is it not natural to suspect that an analogy might help a student to understand the theory after it has been developed. (p. 113)

Supporters of the above position fail to recognize that scientists and science educators are utilizing analogies in two qualitatively different ways. Scientists use analogies to suggest hypotheses. Science educators, on the other hand, introduce analogies to explain or test previously formulated hypotheses.

Research has consistently reported this faith in the power of analogies to teach scientific concepts to be unfounded. Table I

summarizes studies which have investigated the contribution analogies make to students' comprehension of scientific concepts.

Additional researchers have suggested Piagetian level may be an important variable to be considered when investigating analogical reasoning (Levinson and Carpenter, 1974, Lunzer, 1965, Orlando, 1971, Sheppard, 1975). Unfortunately, none of these studies were concerned with comprehension of scientific concepts or the effect of analogies on achievement. Studies noted in Table I investigated comprehension and achievement in science education, but did not control for Piagetian level.

This study was designed to combine these two areas of research to examine relationships among analogical reasoning, Piagetian level, and physics achievement.

Purpose

Questions prompting this study were:

1. is the interpretation of paragraph analogies a form of analogical reasoning?

2. When an individual reads a paragraph containing an analogy, does he/she perceive the relationship being presented?

3. Is it necessary to be formal operational in order to comprehend an analogy?

4. Is analogical reasoning related to proportional reasoning?

5. Is physics achievement related to analogical reasoning?

Subjects

Thirty-seven students enrolled in a university-level, introductory physics course voluntarily participated in this study. A majority of the students were premedical majors and thus, may have been more highly motivated than typical physics students to achieve a high grade. Since the course was offered during the summer term, approximately half of the students attended other universities during the fall or spring terms.

Instrumentation

Verbal Analogies contained two subtests, VBA1 and VBA2. VBA1 utilized a multiple choice format with formal, degenerate analogies having the structure A:B::C:x. Items possessing causal relationships were selected from an analogies test developed by Goldstein (1962). VBA2, developed by the author, contained paragraph analogies taken verbatum from the course text. Each paragraph analogy was followed by four formal, degenerate analogies using terms from the paragraph. Subjects were required to select the formal analogy containing the same relationship as the analogy embedded in the paragraph. VBA1 measures analogical reasoning ability, while VBA2 was designed to determine if subjects possessing that ability are able to apply it to the course text.

Physics achievement was represented by a subject's total point accumulation (final grade). By combining scores on the midterm exam, final exam, and daily homework quizzes, a total of 630 points could be accumulated.

Nonclinical tasks taken from the work of Kuhn (1977), Lawson, Karplus, and Adi (1978), and Collea (1978) were selected to measure student abilities with respect to four Piagetian formal operational schemata; combinations, proportions, probability, and correlations (see Appendix 1). One clinical proportions task, Inhelder and Piaget's shadows task, was also administered.

Procedure

Tasks were administered in three consecutive sessions during the time scheduled for laboratory work during the first week of the term. Subjects were divided alphabetically by last name into three groups. Each group of subjects recieved the tasks in a different order to control for learning effects.

Scoring

Scoring protocols reported in Lawson, et al (1978) were used for nonclinical measures of formal operational thought. Scoring of the shadows task is described in Baker (1979). Both analogy subtests were given a score based on the total number correct for that subtest.

Results

Table II lists Pearson correlation coefficients for all variables. A correlation of .54 between VBA1 and VBA2 suggests subjects possessing analogical reasoning abilities are able to successfully apply that ability to paragraph analogies.

With the exception of the correlations tasks, VBA1 has significant correlations with all measures of formal operational thought. Correlations

between those measures and VBA2 are not significantly different from zero. Neither of the analogies tasks have correlations with final grade that are significantly different from zero.

There were no significant differences between the mean scores of male and female subjects on any measure.

Conclusions

Results of the study suggest the following conclusions.

1. Paragraph analogies do require the application of analogical reasoning.

2. Formal, degenerate analogies do have a proportionality component. However, that component is not important to the solution of paragraph analogies.

3. Formal, degenerate analogies do require formal operational thought. Paragraph analogies do not require formal operational thought.

4. Correctly extrapolating the relationship in a paragraph analogy does not significantly enhance physics achievement.

In agreement with similar conclusions reported by Levinson and Carpenter (1974), this study suggests it is no longer reasonable to assert that analogical reasoning requires proportional abilities. It is more reasonable to suggest proportional abilities are applied coincidently with analogical reasoning abilities only when solving formal, degenerate analogies. Paragraph analogies may supply information that make proportional reasoning unnecessary. In other words, there is no causal link between proportional and analogical

reasoning, as each may be applied independently of the other.

Exactly the same case may be made for the relationship between analogical reasoning and formal operational thought.

The conclusion of this and other studies, that analogies found in science texts do not enhance achievement, may be explained as follows. Analogies found in textbooks are utilized to introduce or explain previously formulated concepts. Yet, prior research indicates analogies only suggest hypotheses related to the desired concept (Scott, 1963, Searles, 1948, Hesse, 1974). Conclusions regarding the concept cannot be drawn from analogical relationships.

Thus, the reason analogies do not significantly contribute to physics achievement is that they are being used incorrectly. If they were instead used to suggest hypotheses related to a concept which could then be tested or explained by other means, then we might find analogies do enhance achievement and comprehension.

Table 1

Studies Relating Analogy Use to Comprehension, Problem-Solving, and Achievement

Investigator	Subjects	Number	Result
Bates (1970)	Grade 6 Elementary Sci.	97	Analogies do not aid problem-solving.
Bielinski (1973)	Grade 9 Physical Sci.	155	Analogies do not aid comprehension.
Dowell (1968)	Grade 10	60	Analogies do not aid achievement.
Dreistadt (1969)	College students	80	Pictorial analogies do aid problem-solving.
Drugge & Kass (1978)	Grade 10 Chemistry	1258	No aid to comprehension.
	Grade 8 General Science	814	
	Grade 9 General Science	100	No aid to comprehension.
	Grade 9 General Science	81	No aid to comprehension.
Reed, Ernst, & Banerji (1974)	College students	97	Analogies do not aid transfer in problem-solving.
	College students	54	
	College students	75	

Table II

Correlation Coefficients of Tasks and Final Grade

With Formal and Paragraph Analogies

Task	Formal Analogies--VBA1		Paragraph Analogies--VBA'	
	r	n	r	n
VBA1			.54***	36
Combinations	.41**	32	.27	32
Proportions	.51***	32	.25	32
Shadows	.51***	36	.28	36
Probability	.46**	29	.28	29
Correlations	.29	34	.17	34
Final Grade	.27	31	.25	31

*** p .001

** p .01

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Appendix

Tests*

*Copies of tests will be sent on request.